ACOP Structural Analysis for PDR

Jih-Long Tsai

March 9, 2005

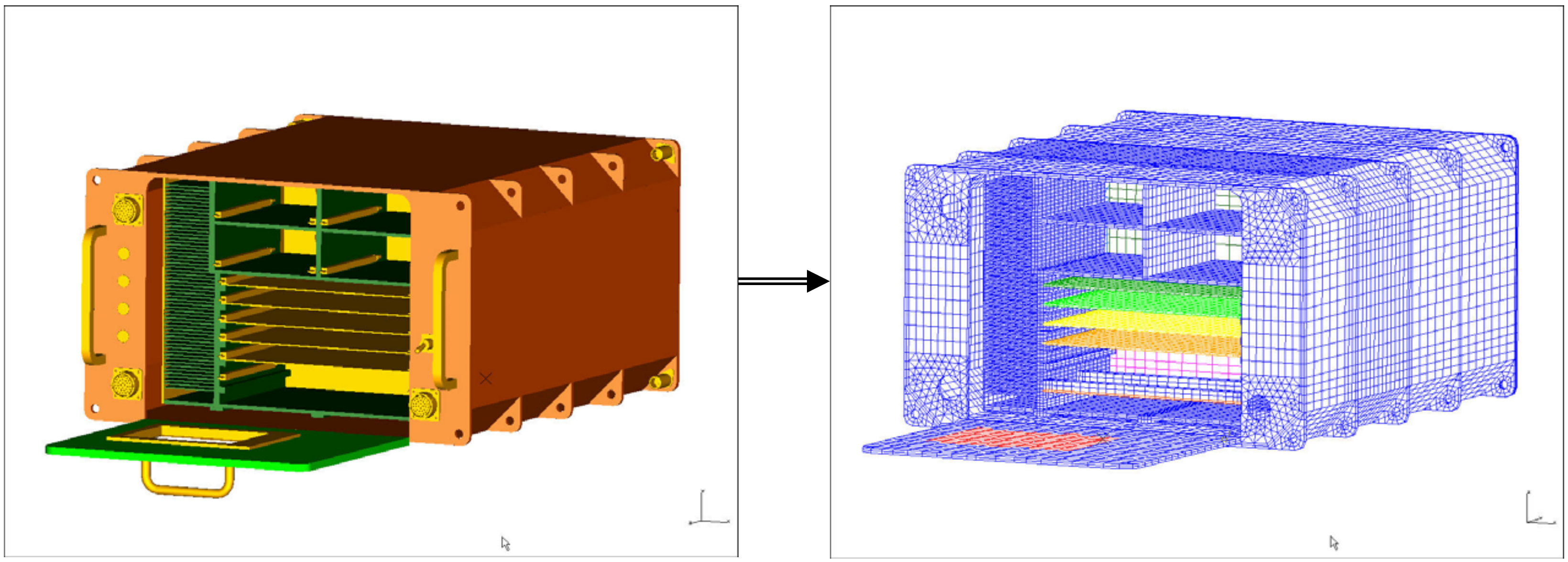
Chung-Shan Institute of Science & Technology

Outline

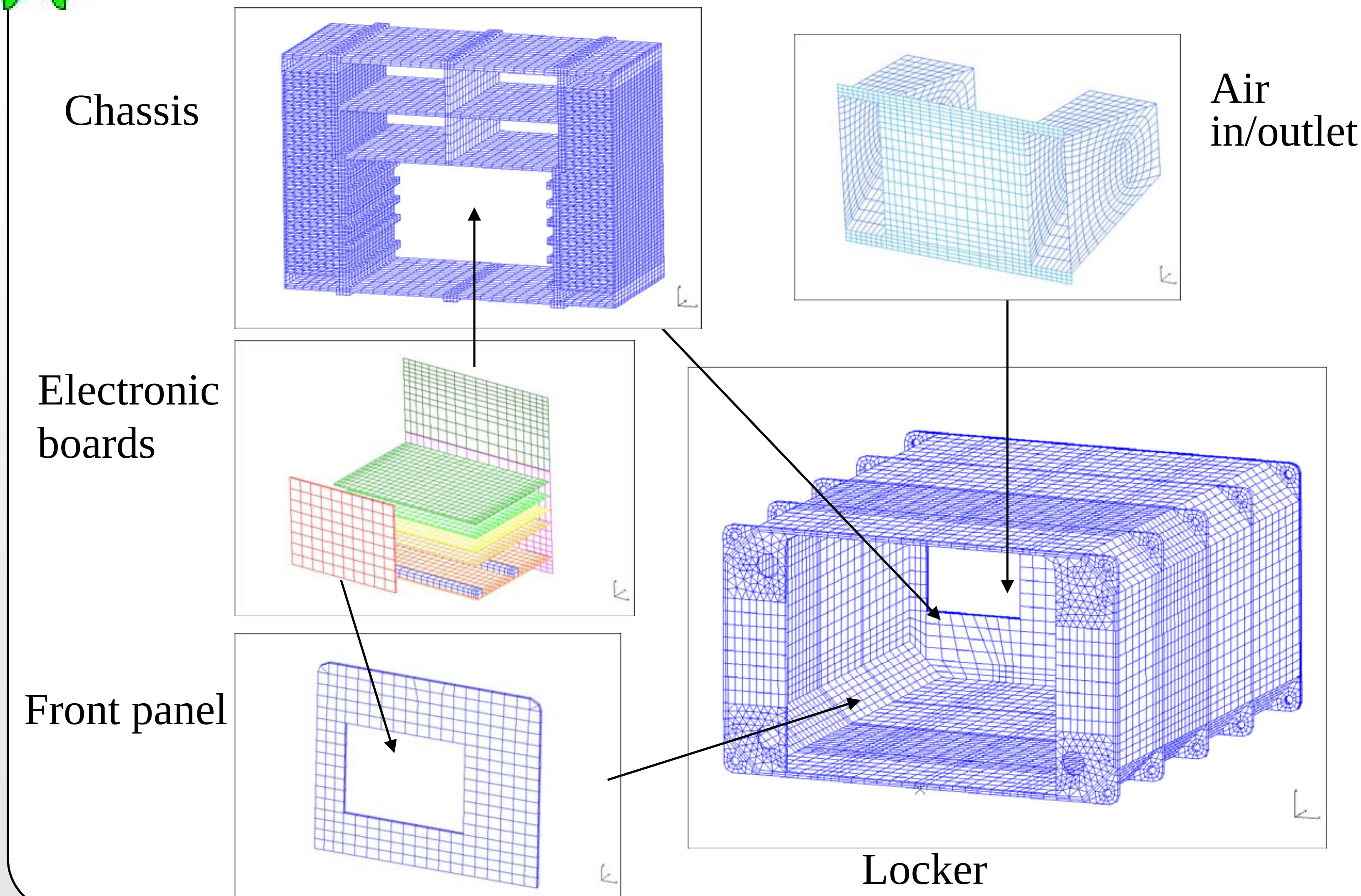
1. FEM Description
2. Compliance Matrix
3. Dynamic Analysis
4. Dimensioning Loads
5. Displacement Analysis
6. Stress Analysis
7. Joint Analysis
8. Conclusion

1. FEM Description

- The geometry of finite element model (FEM) bases on the mechanical design without fans.
- Hard disk drivers are not in chassis during ascent, and not included in FEM.
- The mechanical design and FEM :

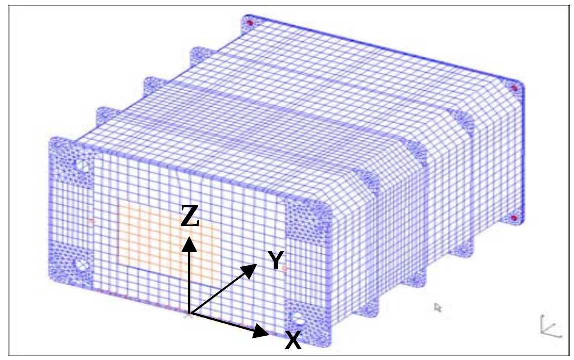


1. FEM Description(continued)

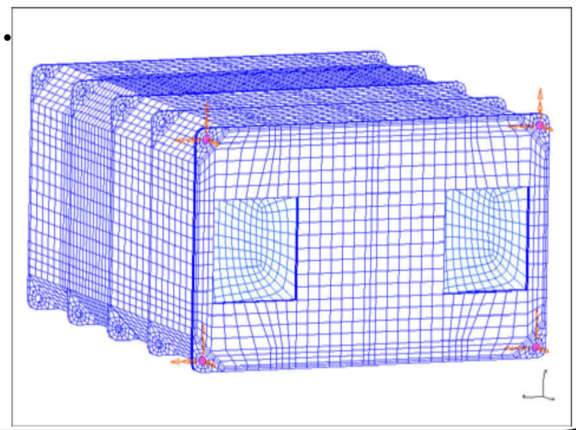


1. FEM Description(continued)

- Used software: MSC/NASTRAN for analysis, EDS/I-DEAS for pre/post processing.
- Model units: SI unit(mass: kg, force: N, length: m, stress:N/m^2).
- Coordinate: These axis directions are same as ISPR coordinate system used in EXPRESS rack payload.



- Material: AL 7075-T7351 for structure.
  FR4 for electronic boards.
  0.97 temperature derating factor is used.



- Boundary conditions:
  Fix all degrees of freedom on each fastened point at backplate.

1. FEM Description(continued)

- Model Mass Budge: (not include connectors, cables, fasteners)

Type	CAD weight (g)	FEM mass (g)	FEM + 10% contingency mass (g)
Sum of Electronic parts	3440.7	3441.1	3785.2
Sum of mechanical parts	23632.2	23735.9	26106.2
Total	27072.9	27174.0	29891.4

- 10% contingency mass is considered to cover the neglected components and manufacture tolerance.

- FEM for ACOP has passed the following model checks:

1. **Model size and geometry**: check element quality.
2. **Free-free and Hardmounted modes**: check only 6 rigid body modes exist in FEM.
3. **1 G check:** the sum of reaction forces equal to the weight of structure under 1 G inertial load.
4. **Strain energy check**: no unintentional constraints exist in FEM.

Through these checks, we can validate the FEM.

2. Compliance Matrix

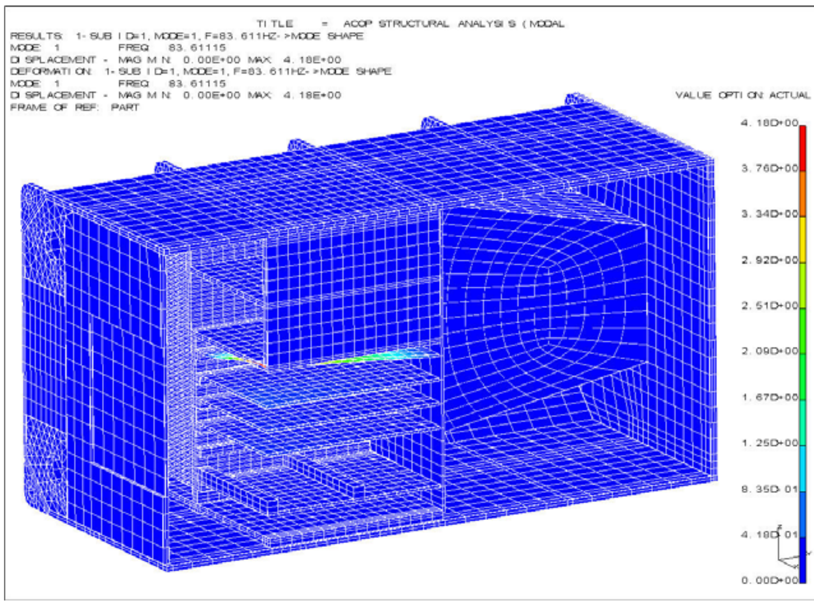
- Red color rows in the compliance matrix are major requirements.

Requirement	Reference	Item	Notes
Minimum natural frequency compatibility	SSP 52000-IDD-ERPE Section 4.1.1.1	EXPRESS payload frequency compatibility	Equal to or exceeding 35 Hz
Minimum natural frequency compatibility	SSP 52000-IDD-ERPE Section 4.1.1.2	Middeck payload frequency compatibility	Equal to or exceeding 30 Hz
Positive margin of safety	SSP 52000-IDD-ERPE Section 4.1.2.1	EXPRESS rack low frequency launch and landing loads	Factor of safety (yielding)=1.25 Factor of safety (ultimate)=2.0
Positive margin of safety	SSP 52000-IDD-ERPE Section 4.1.2.2	Middeck low frequency launch and landing loads	Factor of safety (ultimate)=1.4 Load values are small than EXPRESS rack low freq-loads, will be neglected in report.
Positive margin of safety	SSP 52000-IDD-ERPE Section 4.2.1	Middeck emergency landing load	Only ultimate load. Factor of safety (ultimate)=1.4
Positive margin of safety	SSP 52000-IDD-ERPE Section 4.2.2	EXPRESS rack emergency landing load	May be neglected for analysis using low frequency loads
Positive margin of safety	SSP 52000-IDD-ERPE Section 4.3.1	EXPRESS rack random vibration loads	Combined into EXPRESS low frequency loads
Positive margin of safety	SSP 52000-IDD-ERPE Section 4.3.2	Middeck random vibration loads	Has been included into middeck low frequency liftoff loads.

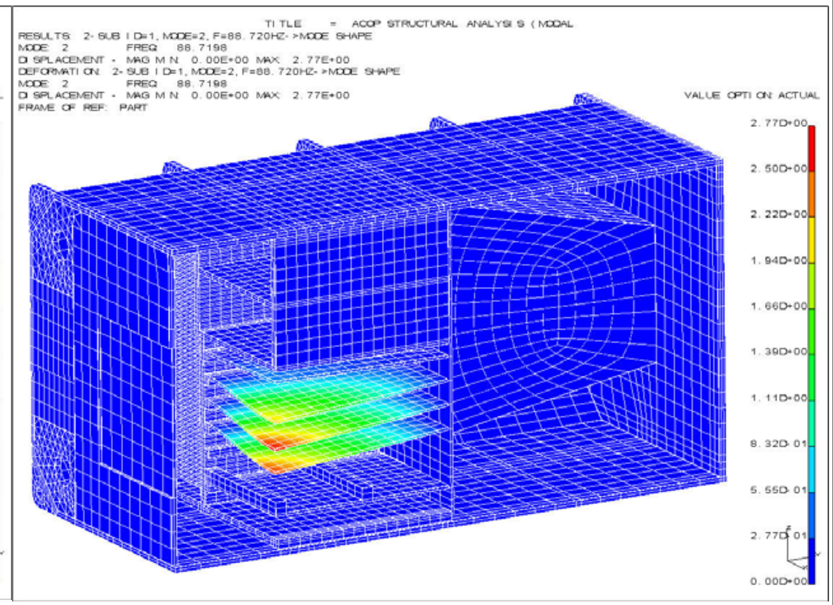
3. Dynamic analysis

- Natural frequency and mode shape:

Mode	Frequency (Hz)	Mode	Frequency (Hz)
1	83.6	17	276.5
2	88.7	20	293.4
5	152.9	53	524.3

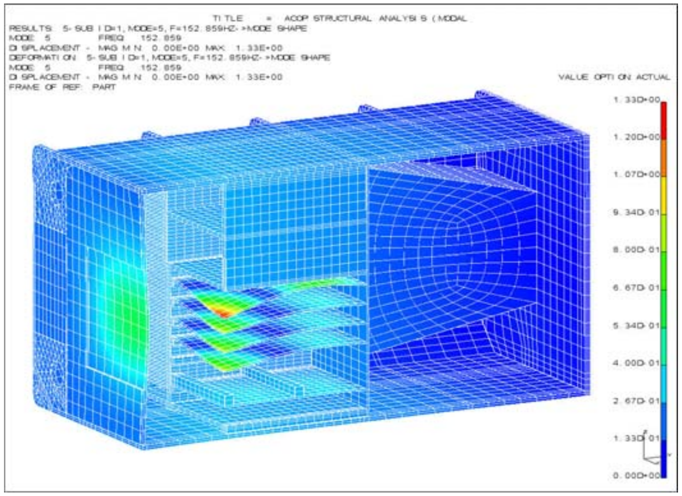


1st mode shape, 83.6 Hz (local mode of the slot-1 board)

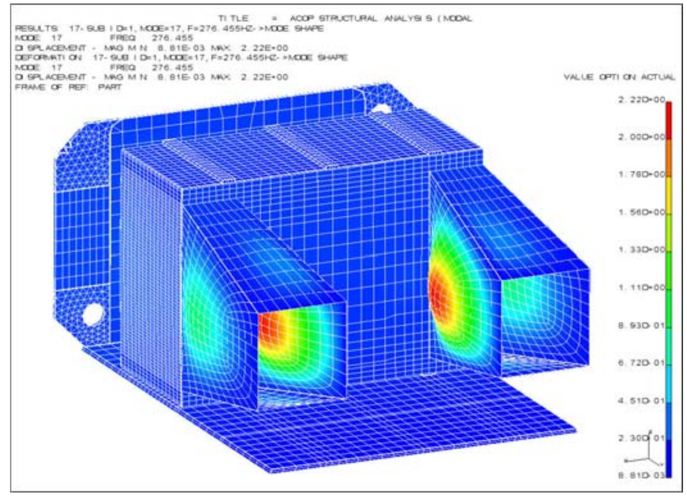


2nd mode shape, 88.7 Hz (local mode of the electronic boards)

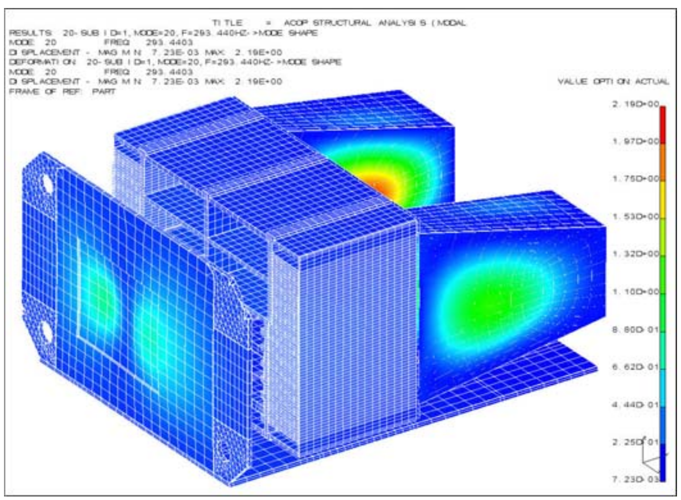
3. Dynamic analysis(continued)



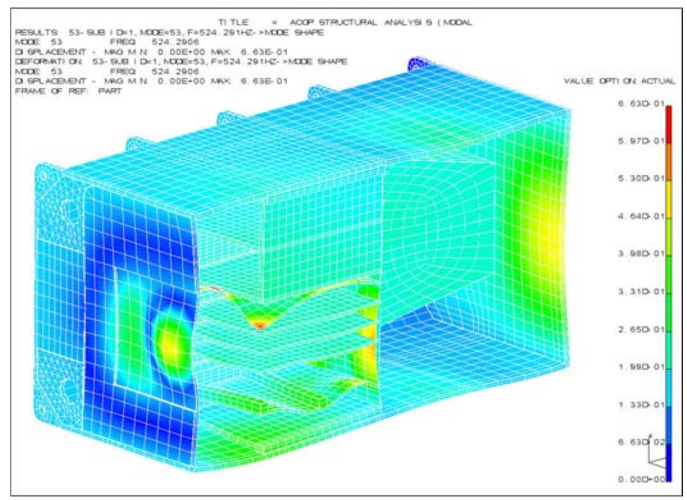
5^{th} mode shape, 152.9 Hz (local mode of the electronic boards)



17^{th} mode shape, 276.5 Hz (mode of air in/outlet side panel)



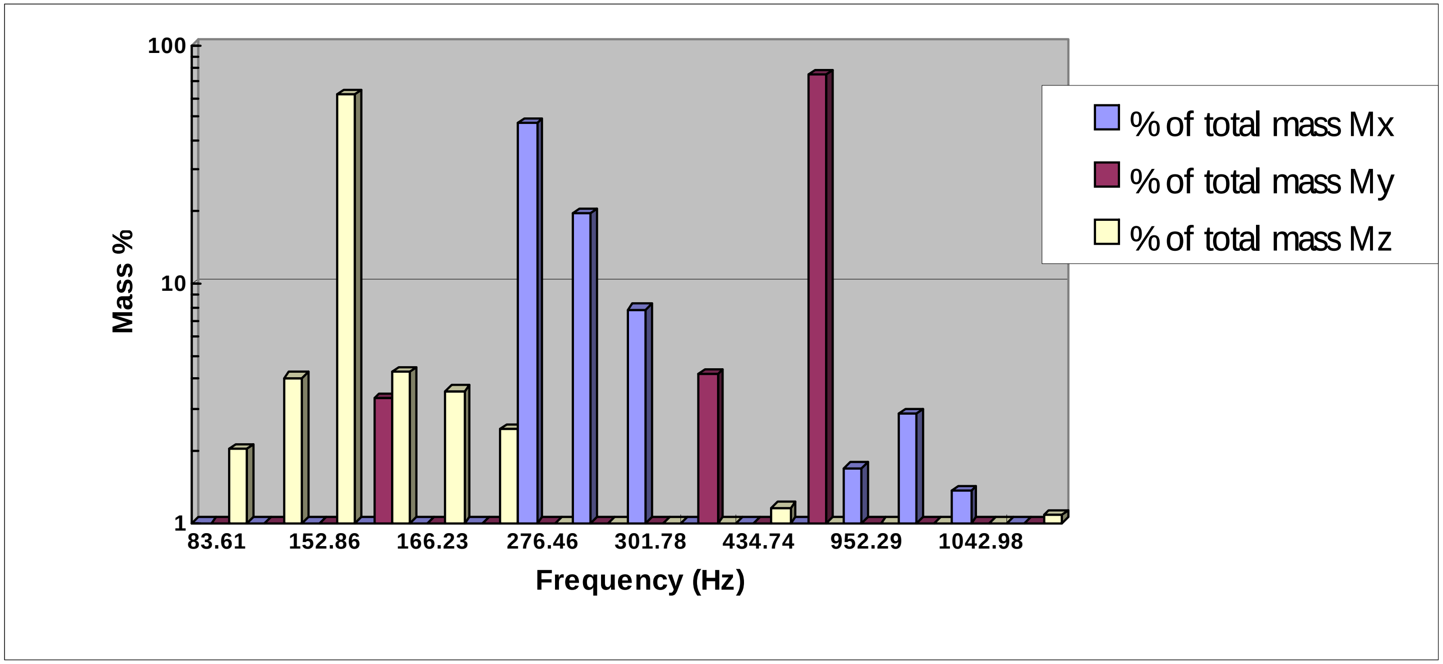
20^{th} mode shape, 293.4 Hz (mode of air in/outlet side panel and front panel)



53^{th} mode shape, 524.3 Hz (global mode in Y axis)

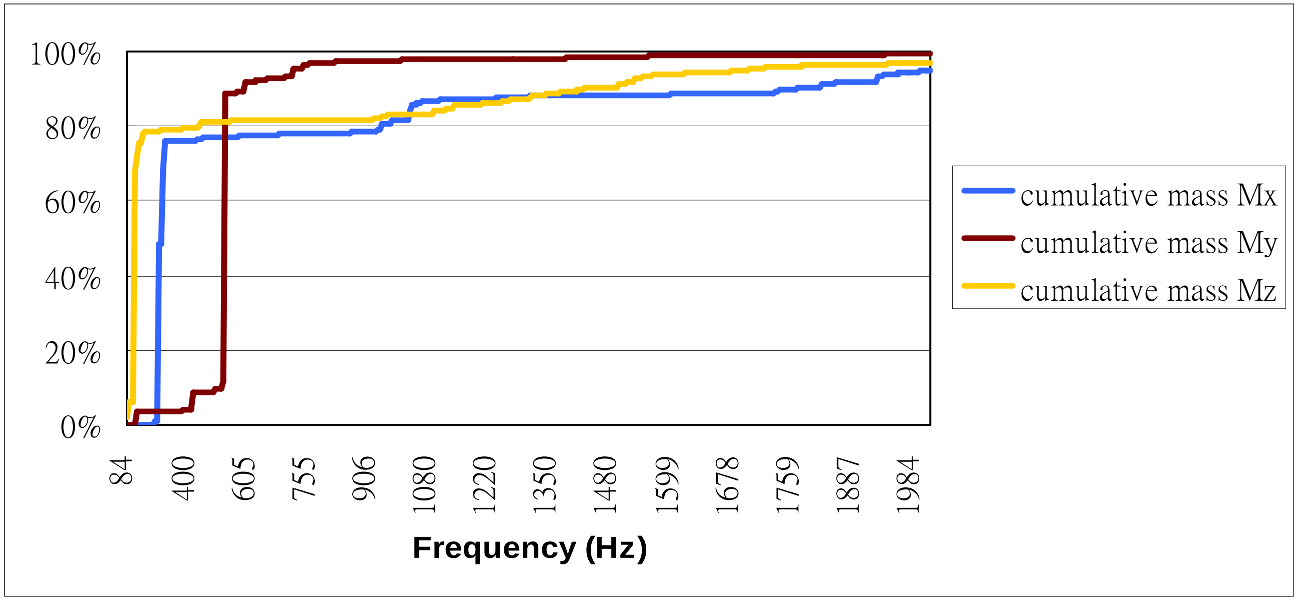
3. Dynamic analysis(continued)

- In dynamic analysis, we get the effective mass for each mode, and choose some significant modes to calculate the combination of loads for stress analysis.



Distribution of the modes with significant effective mass

3. Dynamic analysis(continued)



Cumulative effective masses for all axes

- Choose modes with larger effective mass. And the sum of the effective mass of these modes in each axis is added up to at least 80 percent of the total mass.
- Use these significant modes to combine the random vibration load to low frequency load.

4. Dimensioning loads

- Dimensioning loads:

  Use the methodology of load combination defined in SSP 52005C section 4.2. for significant modes, we get 40 load cases.

1. EXPRESS rack loads :

LOAD CASE NO.	DESIGN LIMIT LOAD FACTORS, G's		
	X-AXIS	Y-AXIS	Z-AXIS
Liftoff			
1~8	16.694,-16.345	± 11.60	± 9.90
9~16	± 7.70	± 21.956	± 9.90
17~24	± 7.70	± 11.60	± 21.738
Landing			
25~32	± 5.40	±7.70	± 8.80

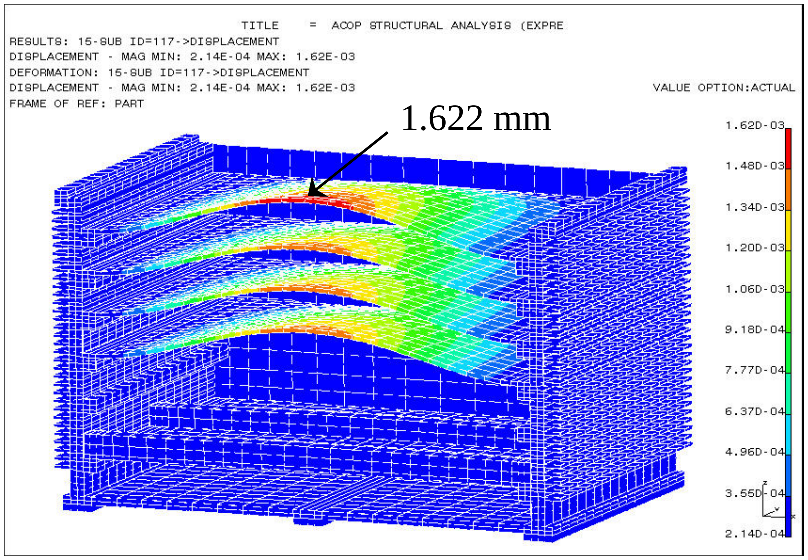
2. Middeck emergency landing loads :

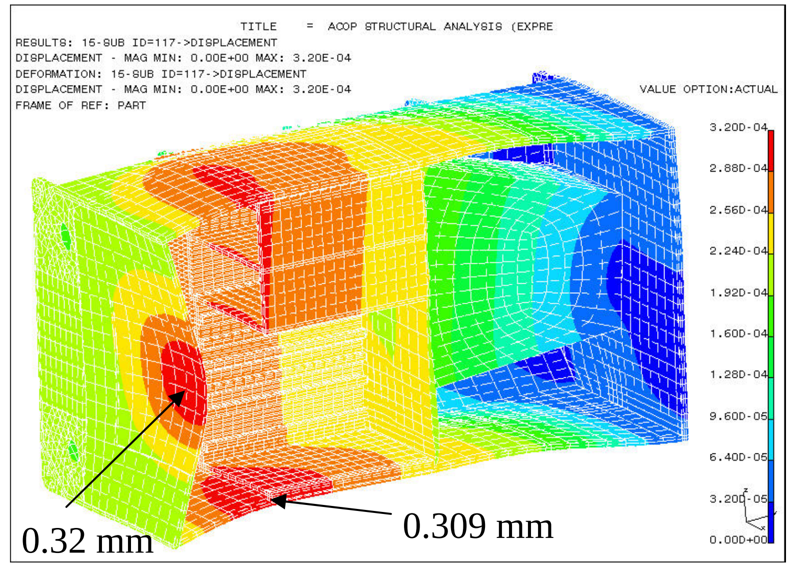
LOAD CASE NO.	ULTIMATE INERTIA LOAD FACTORS		
	X-Axis	Y-Axis	Z-Axis
33~40	+20.0 , -3.3	+3.3 , -3.3	+10.0 , -4.4

5. Displacement analysis

- Maximum displacements are listed as follows:

Load case	Maximum displacement (mm)				
	Locker	Chassis	Ducts	PCBs	Front LCD
10	---	---	---	---	0.4211
17	0.309	0.309	---	1.622	---
19	---	---	0.2404	---	---



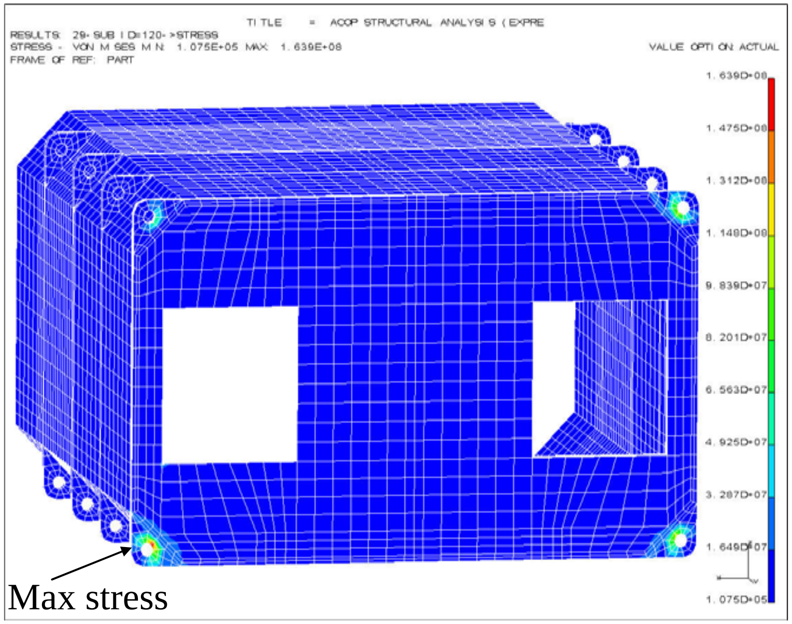


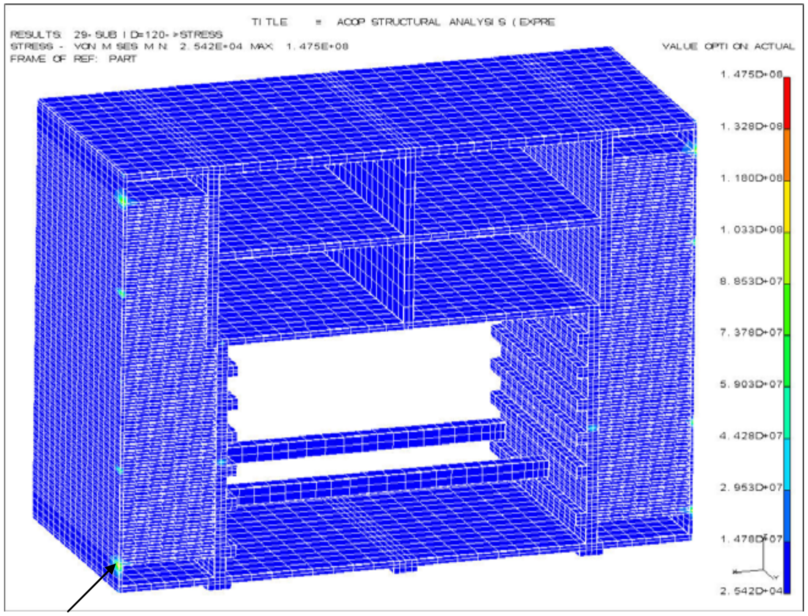
Maximum displacement of PCB, locker and chassis, load case 17
(In order to reduce the max. displacement, two stiffeners will be added to the upper edge and middle line of each PCB.)

6. Stress analysis

- Maximum stresses are listed as follows:

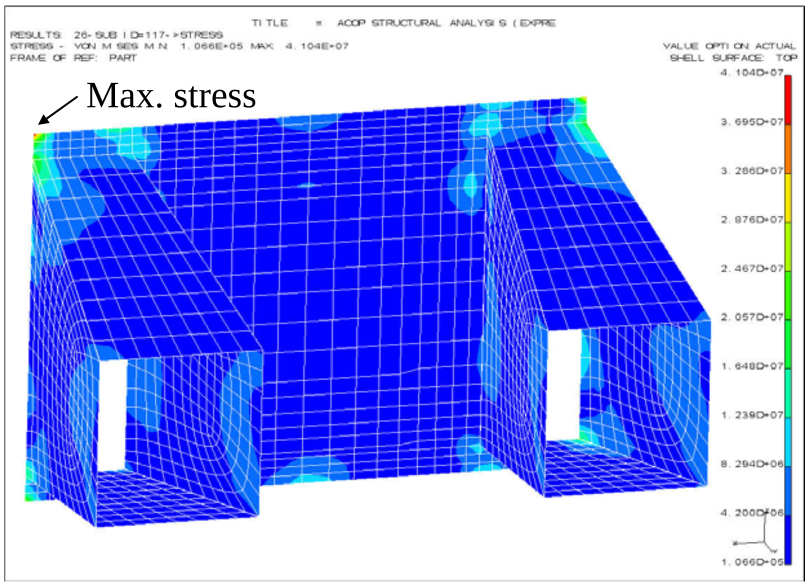
Load case	Maximum stress (MPa, x10^6 N/m^2)				
	Locker	Chassis	Ducts	PCBs	Front Panel
12	---	---	---	---	19.37
17	---	---	41.04	13.49	---
20	163.9	147.5	---	---	---

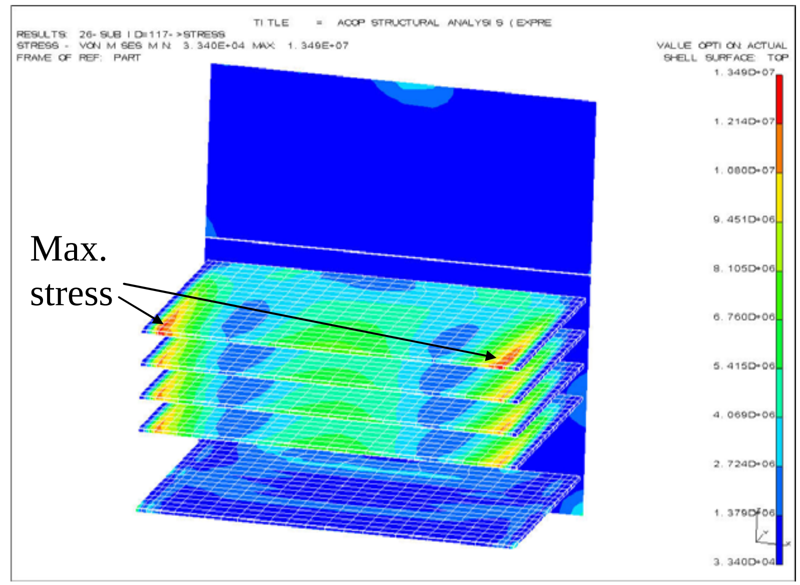




Max. stress in locker and chassis for load case 20

6. Stress analysis(continued)





Max. stress in ducts and PCBs for load case 17

6. Stress analysis(continued)

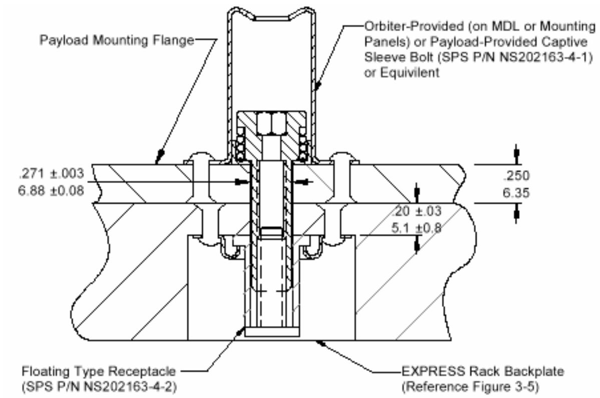
- All margins of safety (MoS) for stress analysis are positive. The minimum MoS is 0.388 occurred at a fastener hole of locker backplate for ultimate stress.

ITEM	Load Case	MATERIAL	Fty [MPa]	Ftu [MPa]	Limit stress [MPa]	$S.F._Y$	$S.F._U$	MoS_Y	MoS_U
Chassis	20	AL 7075 T7351	381.2	454.8	147.5	1.25	2.0	1.068	0.542
Ducts	17	AL 7075 T7351	381.2	454.8	41.04	1.25	2.0	6.431	4.541
Front Panel	12	AL 7075 T7351	381.2	454.8	19.37	1.25	2.0	14.744	10.741
Locker	20	AL 7075 T7351	381.2	454.8	163.9	1.25	2.0	0.861	0.388
PCB	17	FR4	NA	200	13.49	NA	2.0	NA	6.191

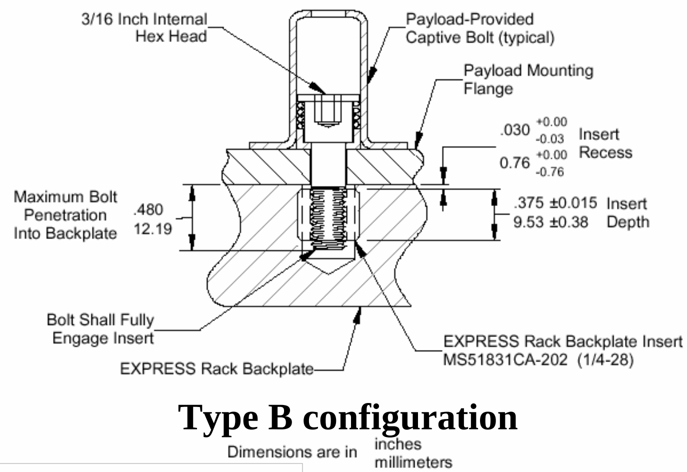
$$MoS_u = \frac{Ft_u}{LimitStress \times SF_u} - 1 \qquad MoS_y = \frac{Ft_y}{LimitStress \times SF_y} - 1$$

7. Joint analysis

- There are two kinds of configurations for the ACOP and EXPRESS rack interface. (from SSP 52000-IDD-ERP)
- The joint analysis includes the bolt check for the bolt strength and the insert check for the floating receptacle.



Type A configuration (current design)



Type B configuration

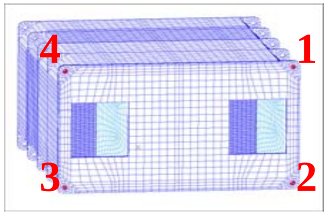
BACK PLATE INTERFACE	INTERFACE CONFIGURA-TION	Ultimate force allowables	
		tensile (lbf)	shear (lbf)
Type A	Sleeve Bolt Receptacle P/N SPS 202163-4-2	2500	1660
Type B	Threaded Insert P/N MS51831CA-202	8900[1]	19600[1]

Notes: 1. Insert limits exceed 160ksi bolt strength.

7. Joint analysis(continued)

- The bolts check : the following table shows max. forces and margin of safety in each bolt. (use 160ksi bolt strength)

Load Definition	joint-1	joint-2	joint-3	joint-4
Axial load (N)	5394.49	5455.02	5464.58	5404.60
Shear load (N)	2521.54	2487.35	2486.98	2521.18
results				
MoS sep	0.524	0.518	0.518	0.523
MoS combU	0.386	0.390	0.390	0.386
MoS bry	5.876	5.97	5.971	5.877
MoS bru	4.465	4.540	4.451	4.466
MoS lug ty	10.734	10.895	10.897	10.736
MoS lug tu	7.750	7.870	7.872	7.751
MoS lug sy	3.509	3.571	3.571	3.509
MoS lug su	3.889	3.956	3.957	3.890



Identification number of joints

7. Joint analysis(continued)

- The insert check : use allowable ultimate force for sleeve bolt receptacle.(tensile: 2500 lbf, shear: 1660 lbf)
- After calculating like the bolt check, MoS for insert is negative.
- MoS summary for joint analysis :

MoS Type	MoS Value	Joint ID
MoS sep	0.518	2, 3
MoS combU	0.386	1, 4
MoS bry	5.88	1, 4
MoS bru	4.47	1, 4
MoS lug ty	10.74	1, 4
MoS lug tu	7.75	1, 4
MoS lug sy	3.509	1, 4
MoS lug su	3.89	1, 4
MoS insert	-0.183	4

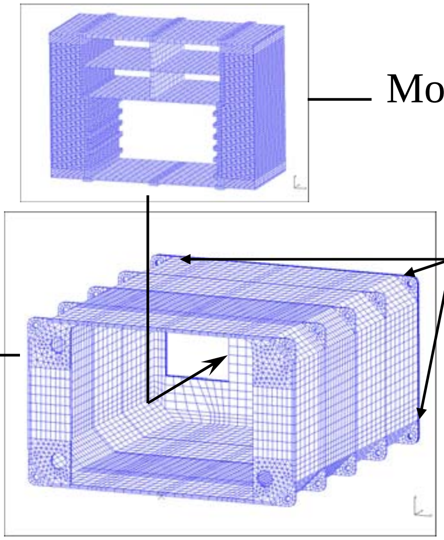
7. Joint analysis(continued)

- ACOP mechanical design may use suggestions as followings for improvement :

(1) Use Type B interface to increase MoS for insert with higher ultimate force allowables.

(2) Move the chassis assembly toward the backplate of EXPRESS rack, then the load will be reduced due to smaller mass moment inertial.

(3) Reduce the weight of ACOP crate, then the load will be also reduced due to smaller mass inertial.



8. Conclusion

- For the dynamic verification the first natural frequency of the ACOP crate is 83.6 Hz that is greater than 35 Hz. It is compliant with the structural requirement.
- The MoS are positive for all applied loads and compliant with the structural requirement except for the insert analysis:

(i) For the stress verification the minimum MoS is 0.388 occurred at a fastener hole of locker backplate for ultimate stress.

(ii) For the bolt verification of the joint the minimum MoS is 0.386 occurred at joint 1 or joint 4 for the combined ultimate load.

(iii) For the insert verification of the joint the minimum MoS is –0.183, It will be increased to positive value by some mechanical design modifications.

- The new structural analysis for mechanical modification is in progress.